DETERMINATION OF POTENTIAL VERTICAL RISE

This procedure determines the potential vertical rise (PVR) in soil strata, such as may be encountered in the placement of a roadway, bridge, or building foundation.

Definitions

- Potential vertical rise (PVR) - expressed in millimeters (inches), is the latent or potential ability of a soil material to swell, at a given density, moisture and loading condition, when exposed to capillary or surface water, and thereby increase the elevation of its upper surface, along with anything resting on it.

- Liquid limit - a test conducted on soil samples as set out in Test Method Tex-104-E

- Plasticity index - a test conducted on soil samples as set out in Test Method Tex-106-E

- Overburden - the soil above the layer or layers being investigated. For example, a clay layer covered with 3.1 m (10 ft.) of sand would have 3.1 m (10 ft.) of overburden on it.

- Layer - a horizontal soil structure of uniform or nearly uniform material. When the material changes due to moisture, density, or composition, a new layer is considered to have been created.

- Loading - the load per unit area in kPa (psf) from both the structure and overburden of each layer involved.

- Moisture Preservation - the use of "Blanket Sections" with wide shoulders consisting of granular materials, stabilized soils, or where asphalt membranes are applied for this purpose.

Apparatus

- Apparatus as listed in Texas Test Methods Tex-101-E (Part I), Tex-103-E, Tex-104-E, Tex-105-E, and Tex-106-E
- Supply of paraffin, small cutting knives, etc.
- Sampling device, core drilling rig equipped to take disturbed or undisturbed samples of the material in place

  NOTE: Undisturbed cores are not absolutely necessary if an approximation of the wet density is known.)

Sampling

Perform exploration and sampling in accordance with the Foundation Exploration and Design Manual of the Design Division, except that greater emphasis must be placed on sampling of top strata layering to a depth of 4.5 m (15 ft.) in most cases, and as much as 6.0 m (20 ft.) when very highly expansive clays are encountered. In some instances, the presence of rock, gravel, or sand substrata will eliminate the necessity for drilling a large number of deep exploration holes. Thicknesses of soil layers, especially clay layers, existing below the proposed structure should be determined. In the case of massive clay layers, the maximum depth to investigate will depend on the position and amount of load proposed and the expansive characteristics of the clay. Secure cores or cuttings to represent these layers. In sampling, all holes should be logged and moisture contents determined.

Procedure

Step	Action
1	If only cuttings were taken during sampling, determine the moisture content of each layer in accordance with Test Method Tex-103-E. If core samples were taken and paraffined for moisture preservation, take samples from the cores for use in this procedure. It is preferable to take moisture samples for each layer at the time of sampling, regardless of whether cores or cuttings were taken.
2	For core sampling, select cores representative of each swelling layer. Trim cores into right circular cylinders using knives or other convenient hand tools. Measure the height, h, and diameter, D, and calculate the volume of the core in cubic meters (cubic feet.) Determine the mass of the wet core to the nearest 0.5 g (0.018 oz.) Calculate the wet density by dividing the wet mass by the volume of the core and record to the nearest 0.02 kg/m³ (0.001 pcf). **(NOTE:** If only cuttings are taken during sampling, use a wet density of 2002.5 kg/m³ (125 pcf), which is usually a reasonable value. Other accepted methods for determining density of cores, such as set forth by paraffin coatings in Test Method Tex-207-F, may be used, if desired.)
3	From representative portions of the cuttings or cores, determine the Liquid Limit (LL), Plasticity Index (PI), and percent soil binder in the soil layers in accordance with Test Methods Tex-104-E, Tex-105-E and Tex-101-E, Part I, respectively. Record the test results.
4	In calculating the PVR, it is convenient or preferable to use 0.6 m (2 ft.) elements or layers, provided the moisture contents and the log of the hole will permit. The use of 0.6 m (2 ft) layers and the assumption of 2002.5 kg/m³ (125 pcf) wet density, which is usually a reasonable wet density, makes the tabulation simpler. The modification caused by using 2002.5 kg/m³ (125 pcf) rather than 2307 kg/m³ (144 pcf), for 22.6 kPa/m (1 psi/ft.), has already been incorporated into the curves on Figures 2 and 3. Where wet densities vary from 2002.5 kg/m³ (125 pcf) and greater accuracy is desired a modification factor should be applied to that layer equivalent to 2002.5 kg/m³ (125 pcf) divided by the actual wet density.
	NOTE: In the 0.6 m (2 ft.) layer at the surface, the "average" load in the layer is 6.9 kPa (1 psi); likewise, in the 0.6 to 1.2 m (2 to 4 ft.) layer, the load is 13.8 kPa (2 psi) for the top 0.6 m (2 ft.) plus one half of the 0.6 to 1.2 m (2 to 4 ft.) layer or 20.7 kPa (3 psi) total. Therefore, the average load in any 0.6 m (2 ft.) layer is the average depth of the layer (subject to the correction factor as described above).

Procedure (continued)

Step	Action
5	Beginning with the logging data for the top layer at the surface of the ground, start compilation of Table 2. Determine average load in each layer (column 2) and record the liquid limit for each layer (column 3) The value of 0.2 LL + 9 represents the "dry" condition from which little shrinkage is experienced, but where volumetric swell potential is greatest. It is the minimum moisture content swelling clays usually dry to. Record this value in column 4. The "wet" condition (0.47 LL + 2) corresponds to the maximum capillary absorption by laboratory tests on specimens molded at optimum moisture and surcharged with 6.9 kPa (1 psi) load. This is also analogous to moisture contents found beneath old pavements or other lightweight structures. This is the "optimum" condition. Record this value in column 5. Determine whether the layers are "wet", "dry", or "average" by comparing actual moisture content with "dry" (column 4) and "wet" (column 5) values. The layer is considered "average" if the moisture content is closer to the average of the "wet" and "dry" conditions. The percent moisture values from the samples are recorded in column 6.
6	Examine the test record forms and enter the percent soil binder (% minus 425 μm (No. 40) material) and the P.I. of the layers in column 8 and 9, respectively.
7	Locate the P.I. of the first soil layer on the abscissa in Figure 1. Move upwards to the appropriate swell line (dry, average or wet) and read the percent volumetric change on the ordinate. This percent volumetric change is for 6.9 kPa (1 psi) surcharge. Record this as "% Vol. Swell" in column 10.
8	The PVR vs. Load Curves in Figures 2 and 3 are for free swelling clays under no load and are based on a wet density of soil of 2002.5 kg/m³ (125 pcf). In order to use these curves, the swelling determined from Figure 1 needs to be converted to the swelling under no load by % Free Swell = (% Vol. Swell @ 6.895 kPa) (1.07) + 2.6. Record as "% Free Swell" in column 11.
9	Determine the PVR's from Figure 2 or 3 as follows: • In the first layer, 0 - 0.6 m (0 - 2 ft.), read the ordinate (PVR) at 6.9 kPa (1 psi) load and the corresponding percent free swell curve and record on Table 2 as "Bottom of Layer". • From the same curve, read the PVR at the "Top of Layer" with corresponding load, zero in the case of this layer. Record on Table 2 as "Top of Layer". • The difference in the two readings is the PVR in the first layer. Record this in column 14. • The PVR value in column 14 is modified when % minus 425 μm (No. 40) (column 8) is greater than or equal to 25 %. The correction factor is equal to the % minus 425 μm (No. 40) material divided by 100. • Correction factors for density are obtained as described in Step 4 and recorded in column 16. • Multiply the difference in PVR (column 14) by the two correction factors (column 15 & 16) and record the results in column 17.

Procedure (continued)

Step	Action
10	Next, take the second layer and determine the percent volumetric swell by modifying the value determined from Figure 1. On this percent volumetric swell curve, or a sketched in penciled curve where the line is not actually on Figure 2 or 3, read the PVR on the ordinate corresponding to 20.7 kPa (3 psi) (bottom of layer) and record on Table II. Read the ordinate corresponding to 6.9 kPa (1 psi) (top of layer) from the same curve and record. The difference in the two readings is the swelling in the second layer, subject to any density or soil binder minus 425 μm (No.40) modifications.
11	Continue determination of PVR in each layer until each swelling layer has been loaded out as determined by the curves on Figures 2 and 3, leveling out horizontally and indicated by no difference when PVR is read from that curve. (Actually the swell is negligible or zero anywhere beyond the end of any given curve as shown on these two figures). Thicker layers may be used in this calculation where they consist of uniform soil having similar P.I. and moisture contents.
12	Check each layer for modifications for density factor and soil binder.
13	Add the PVR in all layers to obtain the total PVR for the site. (**NOTE:** Table 2 has been calculated for no loading due to the structure. When loads due to the structures are known, then simply add it in "Average Load, kPa (psi)" and increase each figure in the column by the amount of structure load, but note that the swell will be reduced because of increased loading.)

Test Report

To report the test results, submit a copy of Table 2 with appropriate job and site identifications.

NOTES

- Often, during design, it is necessary to estimate PVR without knowing moisture contents anticipated at time of construction. In cases of this kind, the design and planning of the job should influence the choice of line on Figure 1 to be selected for use. If the project exists in an arid to semiarid climate and the plans and specifications do not provide for moisture-density control nor preservation of moisture, it is suggested that the line for .2 LL + 9 be used. If the plans and specifications do require moisture-density control and moisture preservation, the average line may be used.

  In the high rainfall areas, the average line may be used where moisture preservation is provided for, but if moisture-density control and moisture preservation are provided for, the lower line (0.47 LL + 2) on Figure 1 may be used.

NOTES (continued)

- The determination of PVR in deep cut sections or deep side hill cuts presents a special case from this test method. In the case of these two conditions, the material is surcharged in such a manner that the movement from swell is mostly in one direction, and in some high rainfall areas could be greater than that obtained by use of these procedures.

- When layers of expansive clays of less than 0.6 m (2 ft.) exist, (Example 1.2 to 1.4 m (4 to 4.6 ft.) it is preferable to enter the abscissa of the proper swell curve at 1.2 and 1.4 m (4 and 4.6 ft.), respectively;, and use the difference in the respective ordinate readings as the unmodified swell in the 0.2 m (0.6 ft.) thick layer.

- At optimum conditions the following relationships are valid from Figure 1:

  - Percent Volumetric swell at 6.9 kPa (1 psi) surcharge = 0.217 • (PI) - 2.9.

  - Percent free swell = 0.232 • (PI) - 0.5.

- For average conditions up to Plasticity Indexes of about 60, the following relationships are valid from Figure 1:

  - Percent Volumetric swell at 6.9 kPa (1 psi) surcharge = 0.294 • (P.I.) - 2.9.

  - Percent free swell = 0.314 • (P.I.) - 0.5.

- Figure 4, giving Family Member Curves, will be useful in determining equivalent swell, such as where a cut is made through a swelling clay hillside. For example, assume that in cutting through a clayey hillside, a soil representing 41.4 kPa (6 psi) load is removed. The 54 P.I. Soil is found to have a moisture content near 0.2 LL + 9 (dry condition). The percent volumetric swell, at 1 psi surcharge, from Figure 1 (top curve) is 16%. On Figure 4 plot the point, 6.9 kPa (1 psi) abscissa and 16% volumetric swell. This point is on, or slightly below, the 20% swell member curve. Now add 41.4 kPa (6 psi) by moving parallel to the abscissa to the point 48.3 kPa (7 psi) abscissa and 16% volumetric swell. This point is on or about the 29.5% family member curve. If necessary, sketch in this curve in pencil similar to the 30% curve and follow this curve upwards to where it crosses the 6.9 kPa (1 psi) load and then read 23.7% volumetric swell on the ordinate. Using the formula, the % free swell (no load) = 1.07 (23.7) + 2.6 = 28.0%. Conversely, if we load the 28% volumetric swell curve with 7 psi load, then the ordinate is 15.5% swell which compares to the original 16%.

Texas Highway Department
Form 513
Rev. 4-63

Sheet 1 of 1

DRILLING LOG

County Williamson Structure Warehouse District No. 14
Highway No. 29 Hole No. 1 Date April 10, 1970
Control 716-3 Station 715 + 30 Grd. Elev. 635
IPE Loc. from Centerline Rt. 300 ft. Lt. Grd. Water Elev. 595

ELEV. (FT.)	Depth	†	LOG	THD PEN. TEST NO. OF BLOWS 1st 6"	2nd 6"	DESCRIPTION OF MATERIAL	Depth	METHOD OF CORING	*
635	0					Sand, f. p grd., tan, loose	0	D. Bbl.	
						Clay, dark brown, wet		P. Bbl.	
						Clay, dark brown, firm		P. Bbl.	
						Clay, red and yellow, firm		P. Bbl.	
						Clay, red and yellow, soft, wet		P. Bbl.	
	10					Gravel, coarse to fine, some moist yellow clay	10	*	
	20					Clay, yellow, soft	20	P. Bbl.	
						Clay, yellow, firm		P. Bbl.	
	30						30		
600									
	40					P. Bbl. Push Barrel	40		
	50					*No good cores obtained due to large percentage of gravel.	50		
	60						60		
	70						70		

*REMARKS:

Driller John Doe Logger John Smith Title Engineering Assistant II

†Indicate each foot by shading for core recovery, leaving blank for no core recovery, and crossing (X) for undisturbed laboratory samples taken.

NOTE: Refer to Foundation Exploration and Design Manual for directions in filling out this form. For distribution, forward one copy to the Bridge Division (D-5) and one copy to the Materials and Tests Division (D-9) if samples are submitted and make a note of same on D-5 copy.

Table 1 - Drilling Log

Depth, m (ft.)	Avg Load, kPa (psi)	LL	Dry .2 LL +9	Wet .47 LL +2	% Moisture	Dry Avg Wet	% -425um (-No. 40)	PI	% Vol Swell (Fig 1)	% Free Swell	PVR, mm (in.) Top of Layer	PVR, mm (in.) Bottom of Layer	Diff. mm (in.)	Mod. -425 um (-No.40) Factor	Mod. Density Factor*	PVR in Layer, mm (in.)
0-0.6 (0 - 2)	6.9 (1)	21	-------	-------	3.1	Dry	100	4	0.0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.00	1.00	0.00 (0.00)
0.6-1.2 (2 - 4)	20.7 (3)	60	21.0	30.2	39.7	Wet	100	38	5.5	8.5	10.41 (0.41)	22.35 (0.88)	11.94 (0.47)	1.00	1.00	11.94 (0.47)
1.2-1.8 (4 - 6)	34.5 (5)	60	21.0	30.2	20.9	Dry	100	38	11.0	14.5	39.37 (1.55)	55.88 (2.20)	16.51 (0.65)	1.00	1.00	16.51 (0.65)
1.8-2.4 (6 - 8)	48.3 (7)	75	24.0	37.3	24.4	Dry	100	45	13.5	17.0	71.37 (2.81)	86.61 (3.41)	15.24 (0.60)***	1.00	1.00	15.24 (0.60)
2.4-3.0 (8 - 10)	62.1 (9)	75	24.0	37.3	36.5	Wet	100	45	7.0	10.0	42.93 (1.69)	46.99 (1.85)	4.06 (0.16)	1.00	1.00	4.06 (0.16)
3.0-3.7 (10 - 12)	75.8 (11)	65	22.0	32.6	8.5	Wet	15	40			n/a+	n/a+	n/a+	0.00	1.00	0.00 (0.00)
3.7-4.3 (12 - 14)	89.6 (13)	65	22.0	32.6	8.5	Wet	15	40			n/a+	n/a+	n/a+	0.00	1.00	0.00 (0.00)
4.3-4.9 (14 - 16)	103.5 (15)	65	22.0	32.6	8.5	Wet	15	40			n/a+	n/a+	n/a+	0.00	1.00	0.00 (0.00)
4.9-5.5 (16 - 18)	117.2 (17)	65	22.0	32.6	8.5	Wet	15	40			n/a+	n/a+	n/a+	0.00	1.00	0.00 (0.00)
5.5-6.1 (18 - 20)	131.0 (19)	85	26.0	42.0	41.5	Wet	100	60	10.2	13.5	89.92 (3.54)	91.95 (3.62)	2.03 (0.08)	1.00	1.00	2.03 (0.08)
6.1-6.7 (20 - 22)	144.8 (21)	80	25.0	39.6	33.9	Avg	100	54	12.6	16.0	123.95 (4.88)	127.00 (5.00)	3.05 (0.12)	1.00	1.00	3.05 (0.12)
6.7-7.3 (22 - 24)	158.6 (23)	80	25.0	39.6	33.9	Avg	100	54	12.6	16.0	127.00 (5.00)	129.79 (5.11)	2.79 (0.11)	1.00	1.00	2.79 (0.11)
7.3-7.9 (24 - 26)	172.5 (25)	80	25.0	39.6	33.9	Avg	100	54	12.6	16.0	129.79 (5.11)	132.08 (5.20)	2.29 (0.09)	1.00	1.00	2.29 (0.09)
7.9-8.5 (26 - 28)	186.3 (27)	80	25.0	39.6	33.9	Avg	100	54	12.6	16.0	132.08 (5.20)	133.86 (5.27)	1.78 (0.07)	1.00	1.00	1.78 (0.07)
8.5-9.1 (28 - 30)	200.0 (29)	80	25.0	39.6	33.9	Avg	100	54	12.6	16.0	133.86 (5.27)	135.38 (5.33)	1.52 (0.06)	1.00	1.00	1.52 (0.06)
9.1-9.8 (30 - 32)	213.7 (31)	80	25.0	39.6	33.9	Avg	100	54	12.6	16.0	135.38 (5.33)	135.64 (5.34)	0.25 (0.01)	1.00	1.00	0.25 (0.01)

Total PVR = 61.47 mm (2.42")

6.1-9.8 (**20 - 32)	131.0-213.7 (19 to 31)	80	25.0	39.6	33.9	Avg	100	54	12.6	16.0	123.95 (4.88)	135.64 (5.34)	11.68 (0.46)	1.00	1.00	11.68 (0.46)

* 2002.5 kPa (125 pcf) wet density assumed for all layers. When greater accuracy is desired use 2002.5 (or 125) ÷ actual wet density of soil in kPa (pcf) as the modifier.

** Note: Since the 3.7 m (12 ft) layer from 6.1 - 9.8 m (20 to 32 ft) is uniform, the PVR may be determined in one reading by useing the "top of Layer" as 131.0 kPa (19 psi) (as in 0.6 m (2 ft) layers) and reading the "bottom of layer" at 213.7 kPa (31 psi) load as in 9.1 - 9.8 m (30 to 32 ft) layer. Readings of 123.95 mm (4.88") and 135.64 mm (5.34") respectively, or a difference of 11.68 mm (0.46"), will be obtained which is a summation of increments (difference) as shown above for the bottom 3.7 m (12 ft.) When layers of expansive clays of less than 0.6 m (two feet) exist, it is preferable to enter the abscissa on the proper swell curve at 4 and 4.6; respectively, and use the difference in the respective ordinate readins as the unmodified swell in the 0.18 m (0.6 ft) thick layer.

*** See example on Figure 2.

\+ n/a = less than 25% minus 425 um (No. 40) material

Table 2

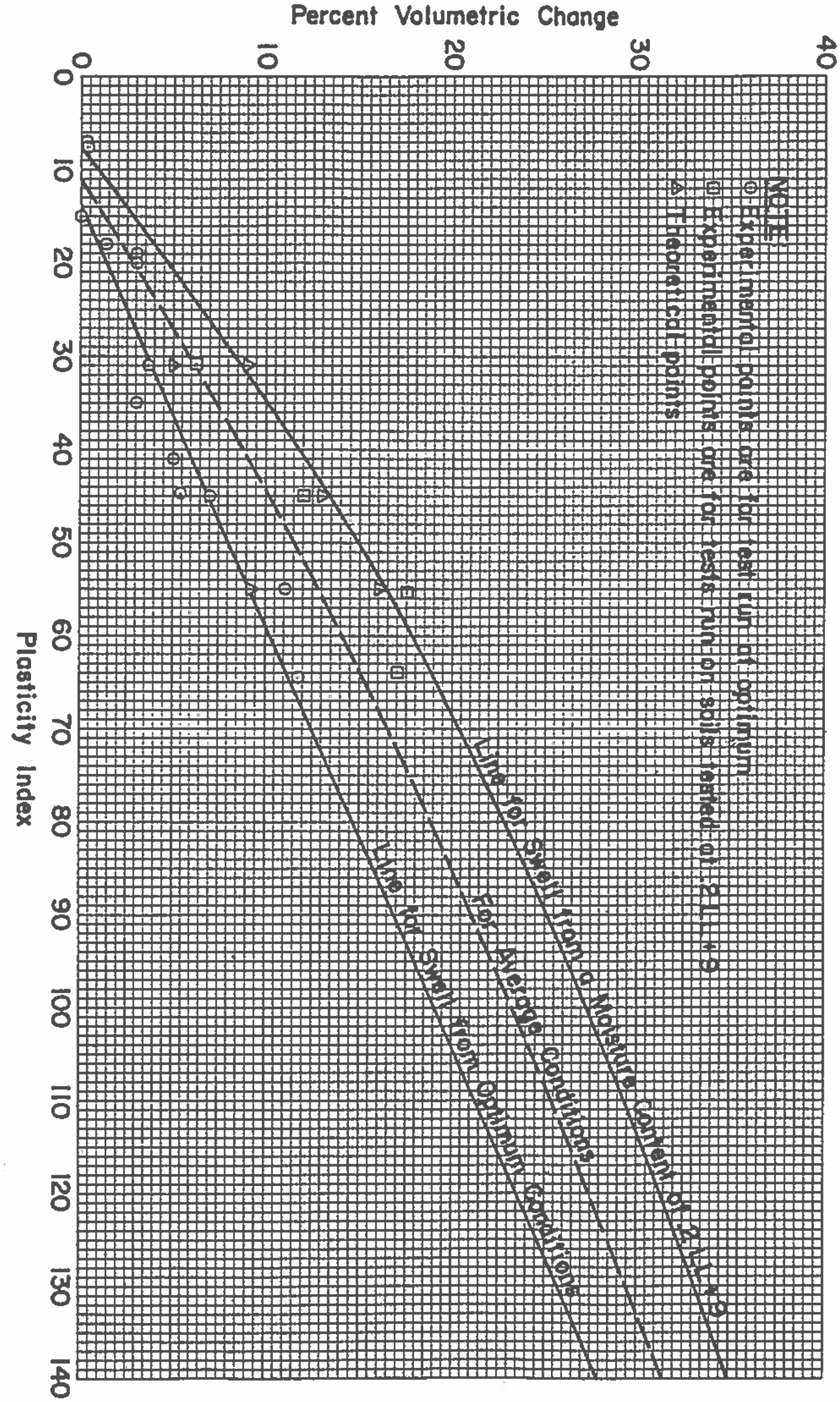

Figure 1 - Interrelationship of P.I. and Volume Change
(Specimens Subjected to Swell Under Avg. Of 6.9 kPa (1 psi) Surcharge)

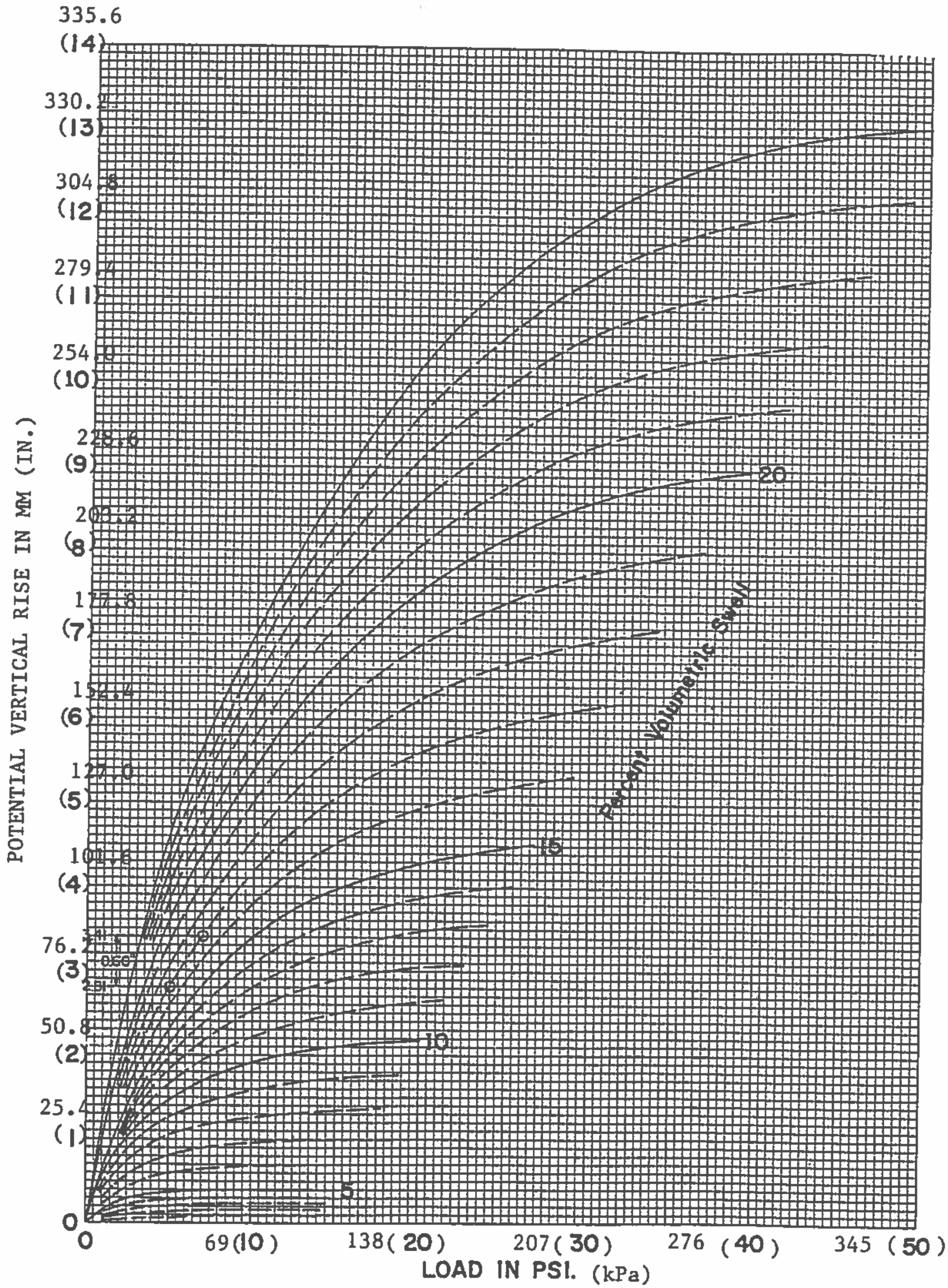
335.6
(14)
330.2
(13)
304.8
(12)
279.4
(11)
254.0
(10)
228.6
(9)
203.2
(8)
177.8
(7)
152.4
(6)
127.0
(5)
101.6
(4)
76.2
(3)
50.8
(2)
25.4
(1)
0
POTENTIAL VERTICAL RISE IN MM (IN.)
0
69(10)
138(20)
207(30)
276 (40)
345 (50)
LOAD IN PSI. (kPa)
Percent Volumetric Swell
5
10
15
20
Figure 2

Figure 2

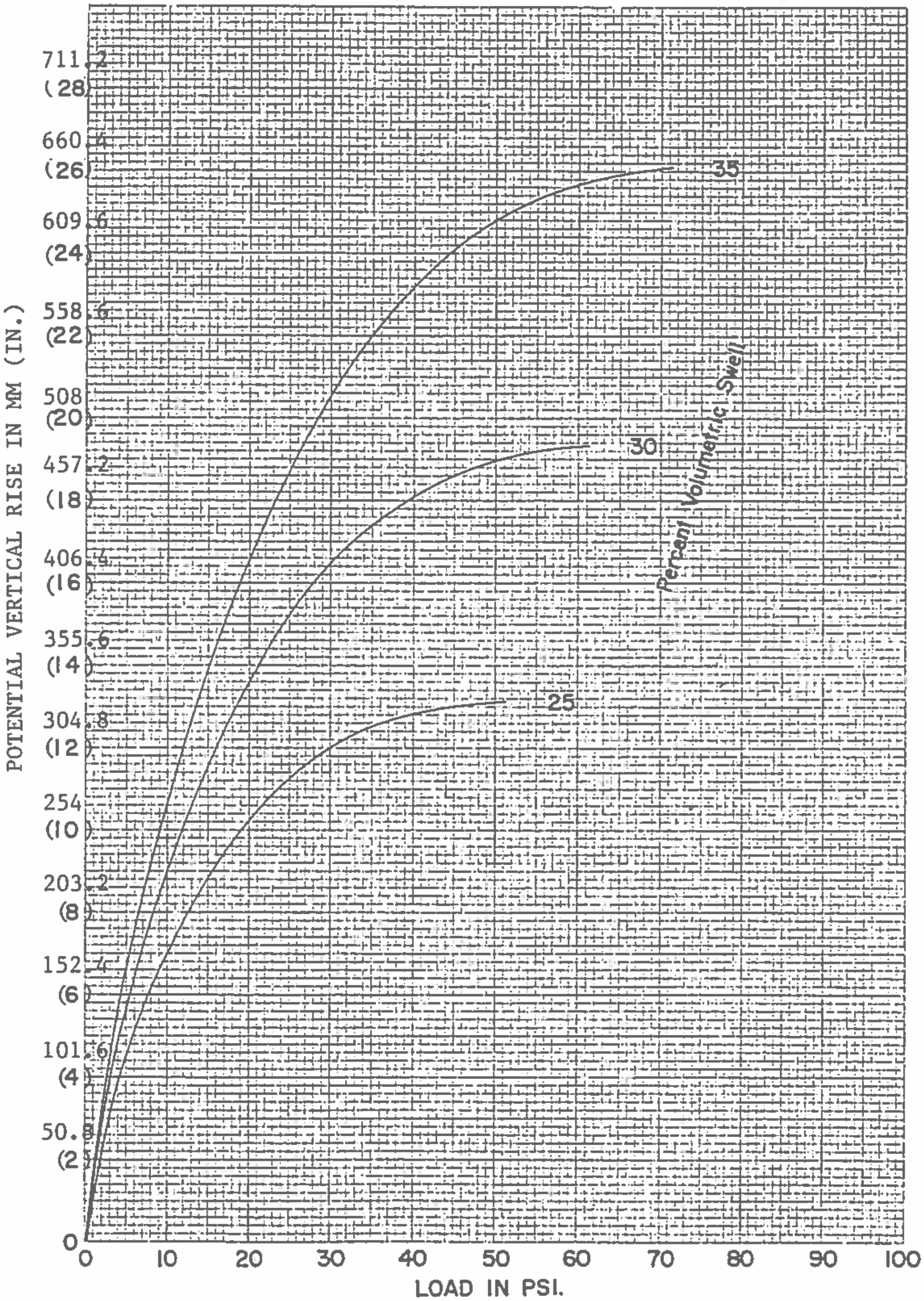
POTENTIAL VERTICAL RISE IN MM (IN.)
711.2 (28)
660.4 (26)
609.6 (24)
558.6 (22)
508 (20)
457.2 (18)
406.4 (16)
355.6 (14)
304.8 (12)
254 (10)
203.2 (8)
152.4 (6)
101.6 (4)
50.8 (2)
0
35
30
25
Percent Volumetric Swell
0 10 20 30 40 50 60 70 80 90 100
LOAD IN PSI.

Figure 3

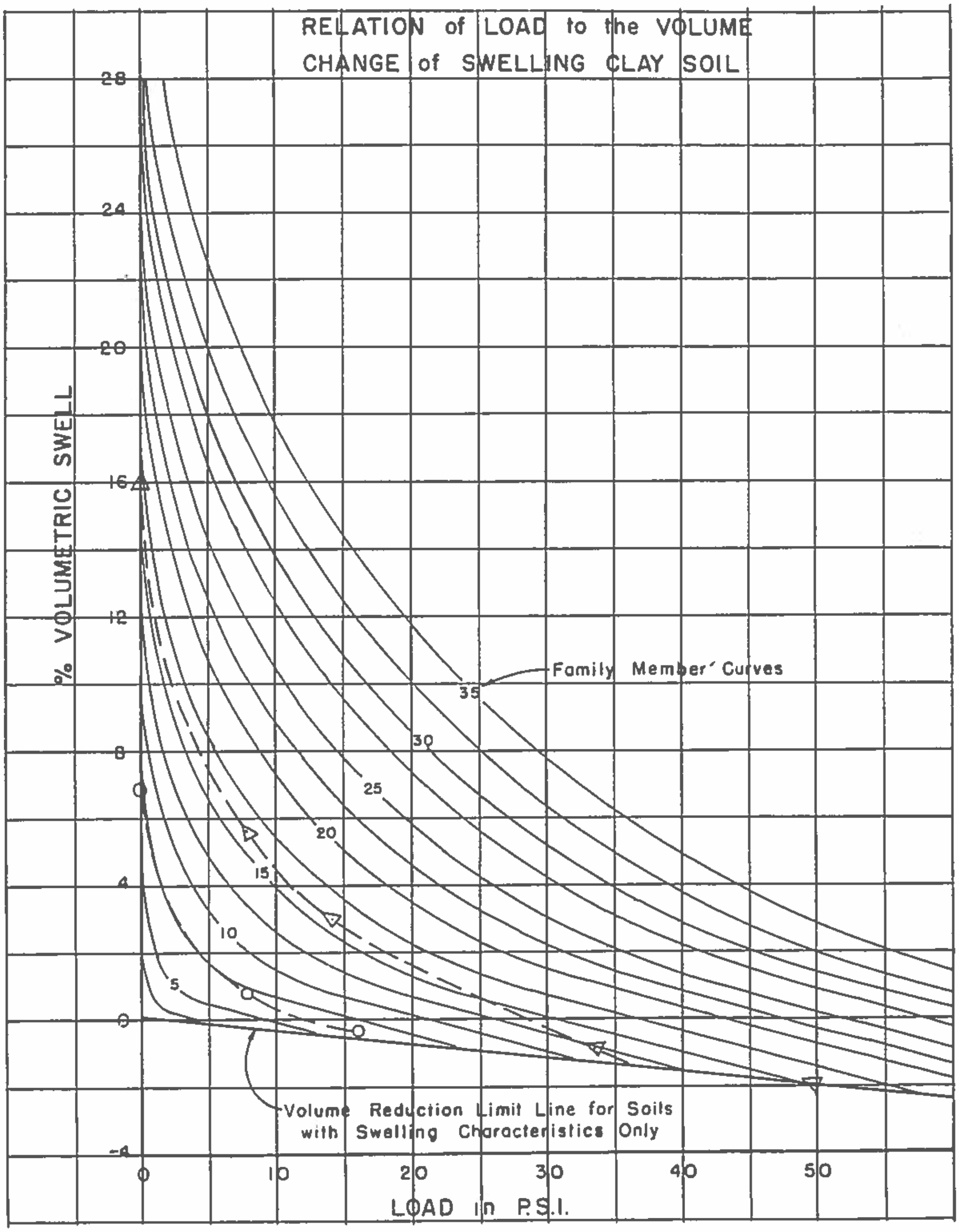

Figure 4 - Relation of Load to the Volume Change of Swelling Clay Soil

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